An Online Learning Community to Conduct Collaborative Education and Innovation in Renewable Energy, Environment, and Manufacturing

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Abstract

The paper presents the development of a multi-university online leaning community for a collaborative project implemented for students for experiencing a real-life situation and enhancing knowledge acquisition in renewable energy, environment, and manufacturing. Widespread interest in green and sustainable industries is resulting from a general recognition of the need for systems that meet societal needs without long-term degradation of the environment. With the growing interest in renewable energy and sustainable technologies, there is a need for individuals with the knowledge and skills necessary to develop and sustain online learning community. A new generation of industry needs to be equipped to function in the interdisciplinary environment typical of sustainable technologies and virtual reality (VR). Two universities are working together to develop a green STEM that prepares participants for careers in the emerging manufacturing industries by enhancing their knowledge in renewable resource development. In order to optimize resources and to utilize expertise at multiple institutions, the program are delivered through online learning community, making it accessible anywhere in the world. The multidisciplinary project involves several different areas of study that directly support VR-based laboratory, including renewable energy, environment, and manufacturing. The approach draws from studies of scientific collaboration, student learning outcomes, and social network analysis. The lessons learned from this round of assessments will be used to improve the collaborative project.

Introduction

The primary aim of this paper is to present an online learning community for improving competitiveness in the global green energy manufacturing environment, and for educating and training students who will form the future work force in the US manufacturing industry. "Globalization" is one of the main trends contemporary business organizations. Globally distributed design, analysis, planning, manufacturing, and quality assurance facilities provide competitive advantages of technology, natural resources, and culture[1-5]. The online learning community evolves from a network of electronic connection into a network for information sharing and integration. This enables the coordination of the network at communication infrastructure based on the information technology and the shared information data flow. The demand for new ways to facilitate learning continues to grow in a globalized world where information retrieval, information sharing, and high communication skills are key, but the means by which these goals may be reached are constantly undergoing technological change. Continuous research efforts are needed to study the impacts and implications of educational technologies and access to education.

In global manufacturing, many components are sourced from several countries, assembled in yet another country, and distributed to customers all over the world. Educators have realized that the online learning community can enhance global manufacturing competitiveness by providing real-time information and enabling collaboration between partners. In addition, engineers must provide solutions to the drivers of change from which we are inspired by a vision that calls us to: Develop sustainable through new technologies and techniques, and respond to the global environmental pressures brought about by economic growth; Be at the forefront of implementing a system design approach across large and small-scale systems; Engage in international collaboration around our critical knowledge and competencies; Work in the emerging technologies to provide solutions in such diverse fields as renewable energy, green manufacturing, virtual reality, and engage in collaboration around our critical knowledge and competencies[6-10].

In a healthy, active learning community, ideas and experiences are shared, and perspectives shaped, through learner engagement and interaction. In facilitating opportunities to learn, it is important to consider the social complexities of interactions. There are three elements of a learning community to consider[11-12], including teaching presence, social presence, and cognitive presence. Teaching presence relates to how the course is designed and facilitated. Social presence is the capacity for students to relate to the group, and the ability to engage in a trusting and safe environment. Cognitive presence relates to the process of how students move towards a common understanding. In the above three phases, it is part of the facilitator's responsibility to establish the appropriate climate for social learning. This goal of this paper is to present the activities of a collaborative project on enhancing green energy manufacturing STEM learning through online communities between DU (Drexel University) and UTEP (University of Texas at El Paso). It is designed to achieve the project goal on the development of virtual reality green energy manufacturing laboratory for enhancement of student learning. The following activities listed in the project have been accomplished and presented in the next section.

Online Learning Materials: Virtual Reality Modeling on Robotics and Renewable Energy for Manufacturing Education

An important role of undergraduate education is stimulating critical thinking and enabling engineering students to be creative while developing analytical skills. Virtual reality is becoming a powerful tool for enhancing student learning by using imagery and haptics to represent and study concepts and notions. Project-based interdisciplinary learning offer students a broader perspective over systems integration while exploring fundamental notions of the topics studied. An undergraduate student explored the VR technology (engine) and developed the framework for a learning module that will present fundamental phenomena in robotics and renewable energy, using a real-like industrial scenario[13-16].

The major tasks described are the description of the developmental platform and the modeling of the VR framework as applied to the following scenario. The learning objectives of the project are aligned with student learning outcomes for each course as students explore concepts as parametric characterization of the thermal system as well as fluid flow characterization for both compressible and incompressible flow. Also, VR technology will enable students to explore new ways to implement their knowledge in a practical manner, enhancing information retention and promoting critical thinking[17-20].

We have investigated the development of VR laboratory for effectiveness of learning outcomes by implementation of final project in MET 205 Robotics and Mechatronics. The final project objective is to understand the use of virtual reality for robotic applications in environment and energy. Virtual reality laboratory is being developed for students to perform the final robotics project at DU. The experience for developing VR laboratory at DU will be used for establishing the MINERSS Laboratory at UTEP, including web-enabled online learning, Internet of things (IOT), etc. MET 205 Robotics and Mechatronics provides the technical introduction of industrial automation of robots. Topics include renewable energy, environment, material handling, group technology, mechatronics-integrated manufacturing, and green manufacturing. This course involves a lecture class for two different batches on Mondays and Tuesdays, and a lab class for both the sections on Wednesdays and Fridays. During lab classes, students are taught the basics of industrial automation and as a part of lab session, students are also allowed to work in groups to understand the use of teach pendants, practice to teach the robot with co-ordinate points, write efficient assembly codes, save, compile and execute to see the robots response to the corresponding code.

The project focuses have been incorporating green energy topics in the final project for EET 320 Renewable Energy Systems at DU. The various projects were assigned to our students with the topics on virtual reality (VR) modeling related to renewable energy, power systems, environment, robotics, or other engineering topics. These projects have become a good example of student-centric green STEM program as well as providing valuable hands-on experience to the students. In addition to providing useful lessons in teamwork and project management, the projects provide a working demonstration of a wind and solar energy system. The goals of all the projects are to explore and enhance student understanding of the green STEM program and how they can be tailored for fast graduation of enrolled students. The objectives of the final project in EET 320 Renewable Energy Systems include: 1. To design a 3D model of Wind Turbine with given blade specifications, 2. To learn to use SOLIDWORKS and Blender to render a 3D model in .obj format, and 3. To learn to script a simple animation in Unity3D VR. The software packages include, 1. 3D Modeling: SOLIDWORKS, AUTODESK, 3DS MAX, 2. RENDERING TO “.obj” FORMAT: BLENDER, MESHLAB, and 3. ANIMATION: UNITY3D.

Figure 1: Virtual reality robotics laboratory

Students are encouraged to design their 3D model in SOLIDWORKS. However, they were encouraged to come up with 3D models through any other software also (Autodesk, 3dsMax). Manual with specific blade designs were provided by Professor, Dr. Richard Chiou to the students during Week 6. At this point the students are asked to work in groups to make this project even interesting to come up with new ideas other than what is given to them. Students are grouped into 4 teams and were given the general steps to proceed with the project. This included the wind turbine blade measurements. The groups were encouraged to improvise on the Wind turbine design. By giving the students the design freedom, we were hoping to see innovative ideas from the groups. The results of this idea are provided in the report session. Students can access the drive link to look into the 3D model designed by the professor using SOLIDWORKS. This model was presented to the students during Week 8 to give them a view of what we were looking for in their 3D design. Though this model is a very detailed one, the groups were asked to turn in a fair model with higher design impact given to the blades to ease their design burden.

Virtual Reality Renewable Energy Laboratory

For 2020 spring/summer, co-op students of the Engineering Technology department worked to implement labs from EET 320 (Renewable Energy Systems) into a virtual reality platform. This project was started before the COVID-19 outbreak, but the pandemic made this research even more relevant with Fall ‘20 classes taking place completely remotely. During this Spring/Summer Co-op period, students worked to build SolidWorks models of various models, generate numerical modeling for the various experiments, and combine these elements within a virtual reality platform in order to effectively mimic a real-time experiment.

Students started by creating a model of a PEM in SolidWorks. Originally, the plan was to do the numerical modeling in SolidWorks as well, but in the end, MATLAB was used due to an inability to secure a SolidWorks add-on to effectively simulate the electro-chemical reaction of a fuel cell. In order to effectively model a fuel cell, and familiarize themselves with this technology, an undergrad student researched and wrote a literature review on similar research projects and the current/future applications of fuel cell technology. The ongoing virtual reality renewable energy laboratory development includes wind turbine, solar panel, hybrid energy, etc.

Figure 2: Virtual reality renewable energy laboratory

This leads to the current build of the Unity scene, which is fully operational, yet still in need of some optimizations. Students can initialize the scene with the application exe, and experience a full, multi-module laboratory. Complete with introductory PowerPoint, physical models for interaction, and fully implemented physical water, numerical, and energy calculation systems.

In order to keep the public updated with our progress on the project, a website was made with WordPress. The goal of the site is to introduce the members of the GreenStem team, give a brief introduction of the different clubs and resources available to students. Once the model is complete, the goal is to have a web-based module for visitors of the site to interact with.

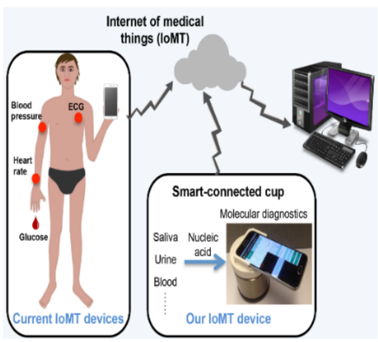
Integrating Online Learning Community with Internet of Things (IoT)

The Internet of Things (IoT) is an expanding, massive network connecting sensors and computing devices embedded in ordinary common things such as appliances, wearable devices, environmental sensors and Smartphones. A subset of the IoT is the Internet of Medical Things (IoMT), an emerging network of medical sensors, diagnostics devices, medical equipment, healthcare data bases, and healthcare providers. The IoMT will likely change the landscape of healthcare, providing better access, more prompt and individualized diagnosis and treatment, customized therapies, and more value healthcare in improving the quality of life. The IoMT will allow Moreover, the IoMT will well widen access to state-of-the-art healthcare in resource-limited areas of the world.   As healthcare spending approaches 20% of the US GDP, engineering students and other STEM majors should consider actively integrating their skills and knowledge with the aim of building the future IoMT to provide sustainable, affordable, accessible healthcare. However, directly addressing medical problems raises many logistic, safety, and regulatory issues and hurdles. We are developing the following Use of sensors and microfluidic devices for bioassays and environmental sensors. Application areas include food safety testing. Students will develop devices to test foods for spoilage, bacterial contamination, toxins, or adulteration.

Many laboratory protocols can be translated and implemented into microscale technologies. Lab-on-a-chip systems comprise miniaturized fluidic networks to process samples (filtration, separation, concentration) and analyze components in samples, often by immunoassay reactions, enzymatic amplification, and some type of optical detection such as color change, optical absorption or fluorescence. There has been much work in developing 'lab-on-a-CD' or 'lab-on-a-disk' systems in which a plastic disk is fabricated by laser machining or 3D-printing to form a microfluidic circuit containing millimeter-sized channels, reaction chambers, filters, manifolds, inlet ports and air vents. The disk is mounted on a controlled motor, and programmed to spin at specified rpms for set times. The centrifugal forces so generated move the liquid samples through various stages. External heaters and infrared detectors provide temperature control. An LED, detector, and optical filters provide optical detection, sensing reaction products that fluoresce or change colors. Thus, entire analytical processes for medical diagnostics (and many other uses including water quality, environmental monitoring, food safety testing, etc…) can be miniaturized, automated, and packaged for convenient use outside of laboratories, such as at the point of care (POC) in clinics, doctors' offices, school infirmaries, food processing and preparation sites, or other venues where rapid, easy-to-use lab tests. Wireless (blue tooth) and cellphone communication and control is also included in the project so the device can serve as a node on the currently evolving Internet of Medical Things (IoMT). The cellphone can provide a user-friendly interface, data acquisition and logging, computer control, communications, and some optical detection capabilities via the cellphone camera.

Pedagogy and Instructional Approach: The instructor was knowledgeable and experienced in developing and engineering assays for medical diagnostics. The students were lectured for about an hour each on the following concepts. Many engineering schools will have faculty, or faculty from other colleges who can serve as a co-advisor in this function.

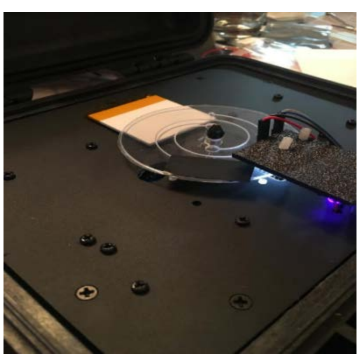
- Biological samples and medical specimens: Students were introduced to the nature of various samples such as blood, urine, saliva, or cell cultures, and the medically relevant information that can be obtained by the analysis of such samples.
- The concept of biomarkers: the presence of proteins and nucleic acids that signal a pathogen infection or disease states.
- Immunoassays: The specific binding of biomarkers to immobilized antibodies and their detection by colorimetry. Over-the-counter drug store lateral flow strips such as home pregnancy test were shown to students.
- Molecular or Nucleic Acid Tests: Students are instructed in PCR (polymerase chain reaction), and newer isothermal nucleic acid amplification methods, both of which use self-contained fluorescent dyes as a reporter of the test result.



<The Internet of Medical Things, including portable diagnostics devise. Figure courtesy of Prof. Changchun Liu, Univ. Pennsylvania>

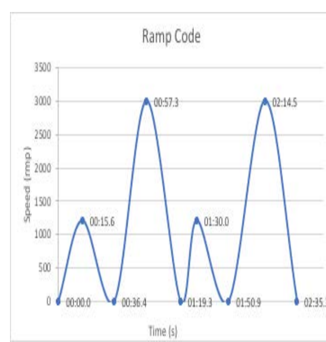
<Microfluidic disk (75mm diameter, 2 mm thick) filled with colored dyes to show channels and chambers>

<Portable case showing lab-on-a-disk microfluidic diagnostics system>



<Closer view of lab on a disk system showing heater (white plate, LED, and optical detector>

<Thermal camera showing uniform heating of spinning disc. With lid of box open and heater on, the spinning disc is thermally imaged>



<Programmed rotation of the disk to execute a microfluidic sequence>

Figure 3: Internet of medical things project learning materials

These are mainstream topics covered in many undergraduate biomedical textbooks. In this project, four students (two Mechanical Engineering Technology, two Electrical Engineering Technology) over the course of eight months, used SolidWorks, CO_2 laser cutting, low-cost 3D printers, inexpensive motors, Arduino microcontrollers, and various optical components (LEDs, photodiodes, infrared sensors) to design, fabricate, and test the system shown. We also emphasize all of the reagents and experimental protocols are available in commercial kits (sold for benchtop laboratory use), so that students only have to translate an established, well-developed method to their novel microfluidic system. Further, safe surrogate samples (included in the kits) can be used for test purposes, so that students never work with any hazardous materials. The materials and components for these projects total less $200 to $300.

Over the past years, we have successfully completed six such medical diagnostics Senior Design projects developing portable medical diagnostics devices in various formats, in addition to the lab-on-a-disk project described here, with students who had little or no formal course work in life science and healthcare related fields. While the ultimate goal is an IoMT medical diagnostics device, numerous engineering subtasks in fluid mechanics, heat transfer, motor control, prototyping, optics, electronics and instrumentation, microcontrollers, and electronics and instrumentation. It provides ample opportunities for students to demonstrate, hone, expand and integrate their skills and knowledge, while simultaneously gaining conceptual understanding and practical exposure in the increasingly important area of medical diagnostics, which plays an essential role to improving the sustainability and accessibility of healthcare, in the US and also resource-limited areas of the world where is little healthcare infrastructure.

Virtual Manufacturing Science Laboratory with Robotic Ultrasonic Welding

In the process of animating this process in SolidWorks, the various positions of the robot were setup so that it can trace the robotic motion and complete the ultrasonic welding process. Figure 4 shows the screenshots from the simulation of ultrasonic welding process. Students learn how to plan the animation for welding parts and further perfect the 3D models in SolidWorks. These 3D models can be used in the virtual environment to create the entire ultrasonic welding process in virtual reality with a similar simulation where the user can interact with the process by setting up the parts, making connections and programming the robot to perform the process. This can be established by importing the models in Unity3D game engine and working with the scripts to bring the animation.

Ultrasonic welding is a relatively fast (1 sec per weld), clean process that does not require adhesives, binding agents, solders, fluxes, or solvents. In many respects, ultrasonic welding is a ‘green’ manufacturing technology in its efficient use of material and energy, and negligible generation fumes, waste or other pollutants. In ultrasonic welding, ultrasonic waves are directed through interfaces between contacted component parts to effect a localized melting and welded bond. In addition to its use for plastics-based fabrication, ultrasonic welding has been developed for metal joining, and is also used for staking (connections made through interference fits) plastic parts. Ultrasonic welding can be used for spot welding and welding continuous seams, the latter of which is critical for making leak-free or airtight systems such as in plastic (micro) fluidic systems, e.g., for point-of-care lab-on-a-chip systems.

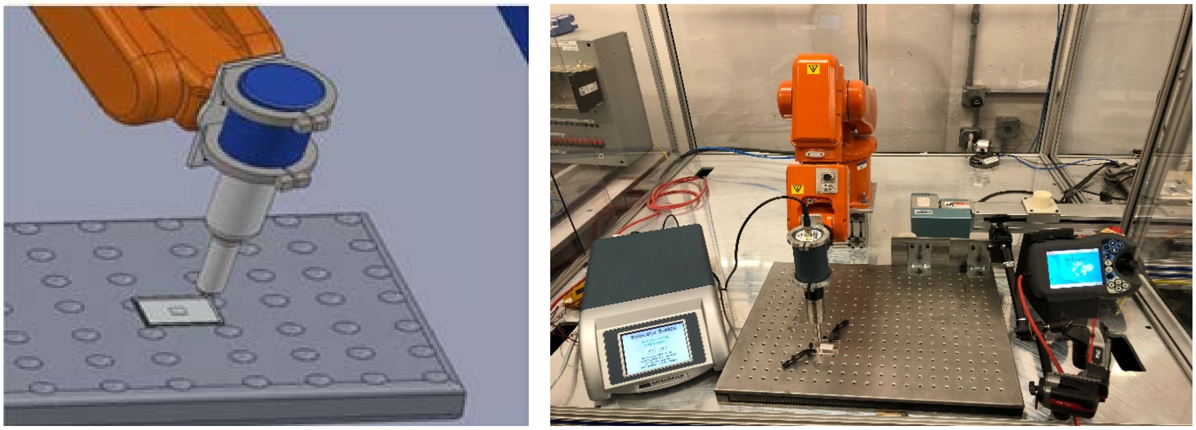


Figure 4: Developing virtual laboratory with robotic ultrasonic welding process

The goal of the project is to develop virtual reality laboratory-based robotic ultrasonic welding process simulations, designed to impress upon users the importance of proper laboratory safety procedures and the potential consequences of not doing so. Robotic ultrasonic welding virtual reality laboratory is developed as an educational project and laboratory component for undergraduate engineering curricula. Ultrasonic welding is a relatively fast, clean process that does not require adhesives, binding agents, solders, fluxes, or solvents. In many respects, ultrasonic welding is a 'green' manufacturing technology in its efficient use of material and energy, and negligible generation fumes, waste or other pollutants. However, complex geometry trajectory and welding path is difficult to weld and can only be done either by an experienced welder or a welding robot due to differences in surface profiles. With a virtual reality based welding simulator, learning ultrasonic welding can be made easier and faster. The broad aim is to integrate robotics and plastic manufacture in a unified theme by 3D design. A secondary aim is to use virtual reality adaptive ultrasonic welding for rapid prototyping as a learning tool for student design projects. Accordingly, educational approaches that combine and integrate multiple disciplines afford more efficient and effective use of time and resources.

Implementing Online Learning Community and Repository

Drexel University has created a website as required for the project. Currently, the website is under construction. Virtual professional learning communities provide teachers with online regional communication and collaboration tools designed to foster high quality STEM instruction. Video conferencing bridges geographic isolation and allows evaluators and schools to collaborate, access training and consultation, and conduct virtual observations. DU and UTEP have online conference monthly meeting. This project seeks the creation of a web-based mentoring program for the learning environment between DU and UTEP. The means of communication will so drastically change that new generations developed distinctive ways of interacting with information. The Online learning community will facilitate the development of a learning environment by sharing known resources, expertise, values, skills, perspectives, attitudes and proficiencies. The learning community allows the learners to build skills and knowledge while attaining goals for career development. Conversely, it provides the opportunity for the experienced individual to further enhance his/her skill and knowledge areas by continuously reassessing and building upon those areas as well as further expand his or expertise in mentoring others in the community.

This collaboration with UTEP is geared toward providing minority students with a path for pursuing and completing undergraduate degrees focused on mastering skills in Engineering, with a focus on Industrial and Manufacturing, Systems, and Green Engineering. The purpose of Green STEM is to establish a collaborative model to aid the development and establishment of an innovative training program for students at DU and UTEP. This project is focused on technologies for green materials, green manufacturing and renewable energy and the ground breaking approach that integrates experiential and research-based learning for undergraduates and graduates through the use of virtual labs based on actual hardware and current research facilities.

Our goal is to better understand and address the roadblocks in engineering that students face, including: pre-college experiences, sociocultural factors, institutional factors, and college experience factors. It is also to provide a positive path forward for enrolling and completing undergraduate degrees with concentration in emerging field of green engineering.

Engaging Social Network with the Online Learning Community

Online discussion spaces for research and development have been growing in popularity across science and humanities disciplines. As they gain popularity, there has been increasing research in how to maximize the learning of these communities. For successful online learning communities, there must be three phases of cognition: triggering, exploration, and integration. The triggering phase is when a student is first prompted to action; they read a topic they are required to respond to and they post their initial reactions to the topic. The exploration phase is when a student is prompted to explore the topic further by the responses they read that other students wrote in the triggering phase. This includes doing further research on a topic in order to support an argument being made against another student's post or exploring other research because a student's attention was brought to another aspect of the topic by another student's initial post. The final phase is the most important and is when the student integrates what they learned from their discussion with other students. The guidelines that the online learning coordinator provide to encourage meaningful participation in the discussion can be categorized as triggering, exploration, and integration.

Green energy manufacturing students at DU and UTEP were given the opportunity and encouragement to discuss their coursework on a social media group page (Google, Facebook, or Blackboard). An online learning coordinator posted weekly topics with questions for the students to answer. The students were asked to respond to the topic in one post and direct another post at any other student that had posted to the topic. Their directed post could be directed at any type of post that another student wrote, either another directed post or a general response one.

The use of start dates, due dates, the minimal number of posts, and the receiving of emails to keeping each member up-to-date on the group activity can be categorized as triggering methods for encouraging communication. This is the initial phase where a student is prompted and reminded to respond to the general topic. Encouraging the students to participate in other people's posts was an integration method for communication. The group page would allow students opportunities to collaborate and interact with other students in the same discipline and discuss their learning and questions they have. Such interaction provides:

- participant engagement through meaningful discussions regarding academic experiences
- support and resources to the student community
- opportunities to share learning and wisdom
- the emergence of a user community centered on the advancement and support of undergraduate engineering students at DU and UTEP

The social interaction among the students allows for the exchange of information that is direct and allows for real-time responses to become instantaneous in comparison with other methods of information exchange. The students are first encouraged to give a brief description of their personal experience and field of study. They then share either course-related material with one another or display general knowledge to other students. The idea and knowledge exchange is beneficial to the understanding of material and to enable students working on time-constrained projects. Assessment reports for different activities will need to be completed annually at each participating institution, and then results will be compiled for evaluation, which includes representatives from all two participating institutions.

Project Outcomes

The green STEM project has been developed on two different campuses in different geographic locations. This collaborative, two-university approach has impacted education in renewable resource technologies in several ways. Students have been taught by faculty from multiple universities in multiple disciplines, providing them a powerful educational experience and the ability to network with diverse experts in the field. Through course sharing and co-teaching of courses, participating institutions are able to offer higher quality curricula, covering topics which may not be available solely at each institution. This program provides an efficient solution to expanding educational demand in emerging areas. In addition, it provides post-baccalaureate students with an educational opportunity that bridges multiple disciplines, is accessible anywhere in the world, and will likely lead to new technological advances in the renewable resources integrated with manufacturing

Conclusion

The online learning community can provide a useful and valuable forum for students and faculty at different institutions around the world to cooperate and exchange information as well as experience at a minimum or no cost. The online learning community provides a great tool for collaboration among institutions around the United States. This can be applied to the area of virtual reality, internet of things, or other areas in engineering education. Students from the participating institutions will have access to the application where they can browse and search the knowledge base and they can also ask their own questions. Instructors from the different institutions will alternate on answering these questions. This collaboration is unique in that it provides students from different institutions access to knowledge base accumulated through the shared experiences of these institutions without much cost. Collaborative learning provides students with opportunities to enhance their interpersonal skills as it further creates an environment where students can also enhance their intercultural competency skills.

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